WARD - REMARKS ON THE B & O RAIL-ROAD - BALTIMORE, 1827

REMARKS,

PROPOSITIONS AND CALCULATIONS,

RELATIVE TO A

RAIL-ROAD

AND

LOCOMOTIVE ENGINES

TO BE USED UPON THE SAME, FROM

BALTIMORE TO THE OHIO RIVER.

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PREFACE.

The successful cultivation of the arts and sciences, marks the inception of the present century. From the direction of the mind to these interesting subjects, discoveries and inventions have recently been elicited, by which the security and happiness of society have been confirmed and established, and the comforts which minister to our social and individual wants, have been largely multiplied. Hence, the genius of invention in the *useful arts*, (more especially in Great Britain,) has of late years obtained for its possessors, honours and rewards in no degree inferior to those which have been awarded to the distinguished individuals who administer to the pleasures of refinement, and of taste, through the creations of genius in the *fine arts.*

Every American, who travels over England with the eye of an observer, must admire the works of art which there so generally contribute to individual and national prosperity. While visiting these, the professional engineer may indulge

in the same feelings of admiration; but it is his business also to acquire a knowledge of the arts by which these achievements have been accomplished. For this purpose, he must devote himself to an analytical investigation of the means by which the materials of genius have been thus ultimately combined and consolidated, and made available to the wants of civilization.

The author of the following pages, during thirteen years past, has directed his attention generally, to the duties and qualifications of a civil engineer, both theoretical and practical, and especially to that department of his profession which relates to steam machinery, and machinery in general, including those which are required on canals* and rail-roads. Although much has been done in Great Britain to render rail-roads and their concomitant engines available to the purposes of transportation, it will be admitted that much remains yet to be done, to bring them to their maximum of usefulness, with less expense of time and money, and to render them capable of being adapted to the bolder geological features of our own country, and to the severity of our winters, more especially in the northern and middle states. Of our numerous advantages on the score of materials; of the necessity of departing from the transatlantic

* See the Franklin Journal, vol. iii. No. 2, page 91.

system of straight rail-roads, or a series of straight portions, with turning platforms at the angles, and of adopting locomotive engines, which will move safely and freely on a serpentine rail-way, I shall hereafter speak more fully.

The bulkiness of the most approved locomotive engines in England, has led scientific and practical engineers, generally, to attach great importance to any improvements by which the weight of these engines may be diminished, and an equal power obtained with a less quantity of fuel. Hence the numerous experiments that have been essayed for improving the steam engine. With a view more especially to accomplish objects so desirable in relation to rail-roads, the author has lately completed a series of experiments on the steam engine, which were commenced in the year 1825. Their results have been witnessed by several scientific and practical gentlemen of this city, among whom was John D. Craig, Esq.,* professor of natural philosophy. From accurate comparative trials, repeatedly made, the saving in fuel and water was $56\frac{7}{8}$ per cent., and it was the opinion of Professor Craig, that by the adoption of certain alterations in the proportions of this engine, indicated by these experiments, that a saving of one hundred per cent. would be effected in fuel and water, or.

* Whose name is used by permission.

in other words, a double power will be obtained by a given quantity of fuel, and weight of engine. A detailed description of this improvement will be given to the public in a short time.

The author has been repeatedly asked, if he thought the contemplated rail-road, from Baltimore to the Ohio river, a practicable scheme; it may now be proper to reply to these numerous interrogatories—that he does believe it to be feasible; and within a reasonable amount of pecuniary expenditure, provided a serpentine route be adopted for the rail-road. By this, he does not mean to imply, however, that the route shall not be as direct as possible within certain estimated limits of expenditure.

MINUS WARD.

BALTIMORE, *March* 29, 1827.

REMARKS

ON THE

BALTIMORE AND OHIO RAIL-ROAD.

In the first place I propose to say something respecting the theory of the locomotive engine. It has been stated by a number of writers in England, that any, the smallest force over and above that necessary to overcome the friction, if continued, would cause the locomotive engine to be continually accelerated *ad infinitum;* and therefore they recommend that the force, when the requisite velocity is attained, should be lessened to prevent the consequences of too great a velocity. Thereby intimating, that it would require no more power to drive the train ten miles per hour, than it would to drive it five miles per hour. This has been denied and answered, see "Operative Mechanic," page 665; but with reference to the steam engine, in a manner not so clear and satisfactory as could be wished.

The error into which Mr. Sylvester and others have fallen, has arisen from confounding what is

to be understood by the words *force* and *power* as used in mechanics: by the word force is meant, the constant pressure, or energy of the moving agent—steam, for instance. This *force* is measured by multiplying the pressure of the steam per square inch, by the number of square inches upon the piston;—but the POWER is measured by multiplying this *force* into the distance passed over by the piston in a given time; or, in other words, by the space over which this force, or energy, is exerted in a given time. Now, if steam engines were capable of exerting a constant, or undiminished pressure upon the piston, under every velocity, in that case, the constructors of locomotive engines would find it necessary to make some provision to prevent their machines from running away with them, and accelerating *ad infinitum:* but the steam engine happens to be possessed of no such extraordinary properties.

The number of cubic inches of steam of a given elastic force, which a given boiler, with a given quantity and quality of fuel, is capable of producing in a given time, is *limited;* and if more steam than this be drawn off from the boiler in a given time, or, which is the same thing, if the velocity be increased, the elastic force will be decreased, and that in proportion to the increased velocity and expenditure. Take a ten horse engine, for

example; here it requires 10000 square inches of the boiler to be exposed to the flame, to generate steam of 25 lbs. per square inch, to feed a cylinder 80 inches area, and 30 inches stroke, making 45 revolutions per minute, allowing four horses for friction within the engine itself. This cylinder has a capacity of 2400 cubic inches, and is filled and emptied twice each revolution; 45 revolutions per minute give us 90 fulls of the cylinder of steam, drawn off and consumed per minute, $2400 \times 90 = 216000$ cubic inches of steam per minute; so that a ten horse engine requires and consumes 216000 cubic inches of steam per minute, of an elastic force of 25 lbs. per square inch, $\frac{4}{14}$ of this being allowed for friction, within the engine itself. The boiler is supposed of a minimum size, in other words, it is made as small and as light as possible, to answer the purpose intended, so that the above sum of 216000 cubic inches of steam *of an elastic force of 25 lbs. per square inch*, is as much as can possibly be generated by it per minute of time. Now it is evident, that an increase of velocity will cause a corresponding increase of the number of cubic inches of steam drawn off from the boiler per minute; but as the boiler cannot generate more than the 216000 cubic inches per minute, of the elastic force of 25 lbs. per square inch, if more than this

be drawn off, a reduction of the elastic force will be the inevitable consequence. Suppose the velocity, or which is the same thing, the number of revolutions per minute, to be increased to double that stated above, this would cause the elastic force to decrease one half,* and still the engine will work to a ten horse power. The calculation would be this: 80 inches area of piston × 12.5 lbs. pressure per square inch = 1000 lbs. pressure upon the piston. Then as the piston passes over twice the length of the cylinder each revolution, it will be 30 inches × 180 = 5400 ÷ 12 = 450 feet, passed over by the piston per minute, 450 × 1000 = 450000 ÷ 32000, the power of one horse = 14,

* This proposition is stated merely by way of argument. Strictly speaking, the reduction, or the increase of the elastic force of the steam, is caused by a reduction or increase of the temperature; and according to the experiments of Dalton and others. (See Thomson's chemistry, vol. 1, article heat.) While the temperature is increased or diminished in an arithmetical progression, the elastic force of the steam is increased or diminished in a geometrical ratio; but this geometrical progression is not an uniform progression, for, according to the same author, the multiplying increments or ratios themselves vary; so that this part of the subject, if we attempt mathematical accuracy, becomes extremely intricate. It is sufficient, however, for our present purpose, to know that an increased consumption of the steam, causes a reduction of the temperature, and consequently a reduction of the elastic force of the steam, in proportion to this increased expenditure, according to a fixed law, until the elastic force is reduced to the point due to the velocity.

as before; and so in proportion for any other velocity. The true theory, therefore, is this: start the locomotive engine with steam as high as you may, the acceleration of the velocity will cause a corresponding decrease of the elastic force of the steam, continually and gradually, in proportion as the velocity increases, the elastic force will decrease, until it is barely sufficient to overcome the friction of the wagons, and resistance from the air, so that the acceleration of the velocity will not be a uniform acceleration, but one whose increments of increase become gradually less and less, until they become so small, as to be imperceptible or inconceivable, after which the velocity is assumed by mathematicians as uniform; and this point, at which the conflicting force, and resistances, come of themselves exactly to a balance, has been called the point of *dynamical equilibrium*. The steam may be raised even as high as the boiler will bear, and the engine be started, and by the time the train has acquired the *maximum* velocity, the steam will be down to the point of dynamical equilibrium. It may happen, indeed, that if the steam be raised very high, before starting, that the *vis inertia* of the mass may be overcome in less time than is required to work down the steam to the point of dynamical equilibrium. In this case the acceleration of the mass may over-

run the point of dynamical equilibrium, and the engine will, for a short space of time, run faster than is due to the generating power of the boiler; but this very excess of speed is that which must, in a short time, bring down the elastic force of the steam, to the point of dynamical equilibrium, as was stated above.

The friction, I believe, from the experiments of Vince, Coulomb, and especially Roberts, (see "Operative Mechanic," page 668,) as also my own experience in these matters, is not increased by the velocity, at least to any perceptible degree. It is stated by a majority of the authors on this subject, that upon a rail-way, perfectly level, one pound applied in the horizontal direction, will move two hundred pounds upon the rail-way. Now, if we assume what is allowed by engineers, that the friction is only the $\frac{1}{200}$ part of the weight of the train, and that the friction is not increased by an increase of velocity, and disregard the resistance of the air, and assume the generating power of the boiler; the number of tons in the train; and suppose the rail-way level, by means of the theory above, (viz: that an increased expenditure of the steam will cause a corresponding decrease of the elastic force of the same, so as to keep the *power* still equal to what it was before;) the velocity of the train, and also the pressure upon

each square inch of the piston, may be calculated thus: Suppose a locomotive engine of ten horse power, with the requisite quantity of water in the boiler to weigh six tons, within which estimate, it is *averred*, it can be constructed, and 18 wagons in train, of 3 tons each. Then 60 tons $\times$ 2240 = 134400 lbs. $\div$ 200 = 672 lbs. This is the force requisite to be applied in the horizontal direction. Suppose the diameter of the wheels of the locomotive engine to be 40 inches, the length of the stroke of the piston 30 inches, and its area 80 inches, the piston, during each revolution, would pass over 60 inches, and the circumference of the wheels = 125.66 inches. The 672 lbs. is referrible to the circumference of the wheel.*

* This can be demonstrated from first principles, thus: The radius of the circle described by the crank = 15 inches $\times$, .6366 (see my demonstration of the crank problem, in the American Journal of Science and Arts, vol. 4th, page 90; also the Technical Repository, edited by Thomas Gill, Esq. London,) = 9.55 inches for the radius of the reduced circle, take this from the radius of the wheel, 20—9.55 = 10.45 inches from the point of the mean action, to the circumference of the wheel. Now, in order to simplify the calculation, we will conceive the cylinder to lay in a horizontal position, and the connecting rod to be infinitely long, or so long as to bring the direction of its action, when at the point of mean action, so near to the horizontal line as to form with it an angle less than any assignable angle, and take the lower position, for example, when the force of the steam is acting between the centre of the wheel, and the point at which the wheel touches the ground; then we shall have a force of 1407.39 lbs. exerted in the direction of the horizon,

The pressure upon the piston must be to that exerted at the circumference of the wheel, inversely, as the distances passed over by the piston and the circumference of the wheel, respectively, 125.66 : : 672 lbs. : 60 : : 1407.392 lbs. pressure upon the piston requisite to give 672 lbs. at the circumference of the wheel; divide this by 80, the number of superficial inches upon the piston, 1407.392 ÷ 80 = 17.6 lbs. pressure upon each square inch, nearly. Now let us see through what space this energy, viz: 1407.39 lbs. must pass in a given time, to give a ten horse power, and this will give us the maximum velocity of the piston, from which the velocity of the train is easily deduced.

directly opposite to the motion of the carriage, and at the distance of 10.45 inches from the ground, and 9.55 inches from the centre of the wheel. The re-action of this force will be exactly equal to it, and in the opposite direction, and exerted at the centre of the wheel. Now, from the known properties of the lever, let us seek for the amount of direct force exerted at the centre of the wheel, in the opposite direction to the motion of the carriage; and the difference between this, and the re-acted force, at the same point, in the direction of the motion of carriage, will be the force with which the centre of the wheel, and consequently the carriage, is urged forward. But this force will be found equal to that exerted at the circumference of the wheel, in a direction opposite to the motion of the carriage. Let x = the force exerted at the circumference of the wheel, at the point of contact with the ground, in a direction opposite to the motion of the carriage; and let y = the direct force exerted at the centre of the wheel, in a direction

A ten horse power = 320000 lbs. exerted through a space of 1 foot, in 1 minute of time, 320000 ÷ 1407.39 = 227.4 feet passed over by the piston in one minute of time. Then 60 (the relative velocity of the piston,) : 227.4 : : 125.66 (the relative velocity of the circumference of the wheel,) : 476.2 feet per minute of time, for the velocity of the train, × 60 = 28572 feet per hour ÷ 5280 = 5.4 miles per hour; and so in proportion for any other velocity, power of engine, or amount of tons in the train; 227.4 (feet passed over by the piston,) × 12 = 2728.8 inches × 80 inches area = 218304 cubic inches of steam per minute, which, at an elastic force of 17.6 lbs. per

opposite to the motion of the carriage. Then, from the known properties of the lever,

$$10.45\ x = 9.55\ y = x = \frac{9.55\ y}{10.45}$$

$$x + y = 1407.39 = x = 1407.39 - y$$

consequently $\frac{9.55\ y}{10.45} = 1407.39 - y =$

$9.55\ y = 14707.23 - 10.45\ y = 20\ y = 14707.23$, divide this by 20 = 735.36 lbs. exerted at the centre of the wheel, in a direction opposite to the motion of the carriage; the difference between this and the re-acted force 1407.39 — 735.36 = 672.03 lbs. the force with which the centre of the wheel is urged forward. But this force is equal to that exerted at the point of contact of the wheel with the ground, in a direction opposite to that of the motion of the carriage; (the small fraction attached to the last number being merely the result of the imperfections of the circulating decimals.)

square inch, is capable of communicating as much power to the piston as 153600 cubic inches per minute, at an elastic force of 25 lbs. per square inch. The difference between this and the 216000 cubic inches mentioned above, as being required for a ten horse engine, being allowed for friction within the engine itself.

To illustrate this subject yet more, let us calculate what will be the speed of the locomotive engine alone, without any wagons in train to retard its celerity, suppose the proportions and powers of the engine as above. Here, 6 tons $\times$ 2240 $=$ 13440 lbs. $\div$ 200 $=$ 67.2 lbs. the force required to overcome the friction of the steam wagon upon the rail-way; then 125.66 : : 67.2 : 60 : : 140.74 lbs. pressure upon the piston, to give 67.2 lbs. at the circumference of the wheel, divide by 80 inches area of the piston, $=$ 1.76 lbs. pressure upon each square inch of the piston.

320000 $\div$ 67.2 $=$ 476.1 feet per minute $\times$ 60 $=$ 285660 $\div$ 5280 $=$ 54 miles per hour. This would be the velocity, supposing no resistance from the air; that is, supposing the wagon to run in vacuo, but owing to the resistance of the air under such high velocities, it would probably not be half that in vacuo.

Tredgold has fallen into an error somewhat similar to that of Sylvester, when he says, in his

treatise on rail-roads, p. 76, (London ed.) that "by enlarging the wheels, any degree of velocity may be attained, consistent with practice." In this he is mistaken; the speed does not depend upon the size of the wheels. These, to be sure, should be made moderately large, but the speed depends entirely upon the *proportion* which the *generating power* of the boiler bears to the *entire mass* propelled. In proof of which, let us suppose the wheels of the steam wagon to be 80 inches in diameter, instead of 40 inches, and let the other parts of the engine remain the same as in the above example, and the weight of the steam wagon and train the same; the friction will therefore be the same, but the circumference of the wheel will be double. Then 251.33 (the circumference of the wheel,) : : 672 lbs. (the friction,) : 60 : : 2814.89 lbs. pressure upon the piston requisite to give 672 lbs. at the circumference of the wheel. Then, in order to find through what space this force must pass in a given time, 320000 lbs. (the power of ten horses,) $\div$ 2814.89 $=$ 113.7 feet passed over by the piston in one minute of time. Then 60 : 113.7 : : 251.33 : 476.2 feet per minute for the velocity of the train, the same as when the wheels were supposed 40 inches in diameter. In this last example, half the number of cubic inches of steam is drawn off from the boiler per minute, of twice

the elastic force. To make the elastic force equal in the two cases, we have only to put the area of the cylinder in the last example, at twice that in the first, viz: 160 square inches; then the piston moving with half the velocity in the last example, that it had in the first, and having twice the area, it will draw off the same number of cubic inches of steam per minute as in the first example, which will reduce the temperature and elastic force to the same point at which it was in the first example; the temperature being kept down in proportion to the quantity of steam consumed. But twice the area × half the elastic force will still give us 2814.89 lbs. pressure upon the piston, which being referred to the circumference of the wheel, still gives us the 672 lbs. at that point, and so in proportion for any other diameter of the wheel.

I now come to a part of the subject more interesting to the general reader, than the mathematical calculations, but which I apprehend presents difficulties, which have not been anticipated by the public. I mean the impossibility of constructing a rail-road in a direct line (right line) from Baltimore to any point on the Ohio river. There is probably but one practical route within the state of Maryland, along which a rail-road could be constructed throughout the whole length

of the state: and that is along the bank of the Potomac river; for if it be attempted to leave the river, and to go parallel to it within the state of Maryland, the vallies of the tributaries of the Potomac, present serious difficulties indeed, (in a financial view.) The vallies are some hundreds of feet lower than the intervening ridges between them. To pass these, it would be necessary to have stationary engines and inclined planes, to descend into the vallies, and other stationary engines and inclined planes to ascend out of them, on to the next succeeding ridges. This would increase the expense to such an amount, as perhaps to be financially out of the question; but setting considerations of cost aside, and suppose the road completed in this manner, the TIME consumed in passing through, would be increased so much as would probably, in a great measure, defeat the object contemplated. This being conceded, we have within this state but the one practical route, viz: along the bank of the Potomac river, which, every body must know, would be a very serpentine route. There is, however, another route, speaking in general terms; and that is, to keep up upon the dividing ridges between the waters of the Potomac and those falling into the Great Gunpowder river, and the waters of the Susquehanna, in the state of Pennsylvania. This route would

also be very serpentine. Now, the most approved locomotive engines hitherto constructed, are those by Losh and Stephenson. But the construction of their wagon is such, that each pair of wheels is necessarily attached to their respective axes, and consequently the axis revolves with the wheels; and of these, one cannot revolve in the least degree, faster than the other. After the bare mention of these facts, any person in the least acquainted with mechanics, will at once say, that such a wagon could not be made to run upon a serpentine road. It will not run on any road without great and fatal friction, except such as are almost mathematically straight; and such a road cannot be constructed from Baltimore to any point on the Ohio river, consequently Losh and Stephenson's locomotive engine is not adapted to this road. What then is to be done? A locomotive engine could be constructed, that would allow of being turned to the right or left, by laying a rack-way in the middle of the road; into this rack-way a cog-wheel works, turned by the engine. But here again we have three difficulties to encounter, which Losh and Stephenson's wagon is not liable to: 1st. The expense of laying a rack-way in the middle of a double rail-way, an aggregate distance of 500 miles, is no trifle, as will readily be admitted. 2d. The friction in those locomotive engines which

have been tried, with rack-ways, has been found much greater than in Losh and Stephenson's plan. And 3d. The cast iron rack-way is very liable to break, and be out of order, while the rails of the road are not impaired, more especially if the latter be made of wrought iron, which is both practicable and preferable, in this country, where good hard stone, in inexhaustible quantities, may be had. But the rack-way cannot be made of wrought iron; and the objection, that it would be liable to break, is of peculiar force, upon the contemplated rail-road from Baltimore to the Ohio river, passing as it must through a mountainous region, and being subjected to great vicissitudes of temperature, and to the accumulation of snow and ice, during some months in the winter, at which time it is also contemplated to use the rail-road. It must strike every one, as a forcible objection, that the ice would collect between the cogs of the rack-way and inevitably break them; and it is also liable to break by any sudden shock, or by the intervention between the cogs, of any hard body, as gravel, &c. more especially when the iron is chilled by severe frosts. From a combination of these causes, it would be almost continually out of order and useless here.

I will now proceed to *propose* a method of construction for a locomotive engine, which will com-

bine the advantages of Losh and Stephenson's wagon, with the capability of turning to the right or left, upon a serpentine road, with as much or more ease, than the system of rack-ways in the middle of the road, and which is as follows:

In this wagon there is an axle-tree for each wheel. A wheel being firmly fastened to one end of each axle-tree. There is a crank on each axle-tree, near to the wheel, on the inside, formed by a double bend in the axle-tree. Conceive two of these axle-trees placed in a frame, one a few inches in advance of the other, with the wheels upon each side of the frame, and the inner end of each axle-tree, extending no farther than the crank upon the other axle-tree. This forms the fore part of the wagon. The hinder wheels are mounted in a similar manner, in a frame to themselves. These two frames are connected together in the manner of ordinary wagons; and upon these frames the boiler is supported, which may be mounted upon floating pistons, as used by Losh and Stephenson, each crank has a separate and distinct cylinder of its own, entirely independent of each other, with valves, &c. complete. The aggregate sum of the numbers of cubic inches which these four cylinders would hold, is to be equal to that of the two, where two cylinders are used; or of the one, where one is used:

in other words, the power is divided into four equal parts, each part being exerted upon its respective wheel. By this plan, in turning upon the curves of the road, the wheels which describe the greater curve can revolve more rapidly than the others, and yet continue to be urged by the steam with as much force as before. The steam being conveyed from the boiler to each cylinder.

The wagon may be kept accurately upon the rails day and night, by means of two guide wheels, in advance of the wagon, to the wheels of which the steam is not directly applied, they being merely impelled forward by the others. These guide wheels bear up no part of the weight of the boiler; but upon the axle-trees of these wheels, the water cistern for the supply of the boiler, might be advantageously placed. Another method of keeping the wheels well upon the rails, would be to omit the guide wheels, and have a portion of a wheel with cogs attached to the foremost frame of the steam wagon, with a pinion working in the same, and a winch or handle upon the upper end of the shaft of the pinion, and an index to point out the angle formed by the two pairs of axle-trees with each other; and this winch to be turned by hand, as the curvatures of the road may require.

Before commencing the survey, or before the actual location of the road, would it not be the safer course to cause a temporary rail-way to be laid down, and to try upon it a locomotive engine of the best construction that can be devised for running upon a *serpentine* road, and thus to ascertain by experiment, the size of the smallest circle, upon the circumference of which the steam wagon would advantageously travel? With this view, the temporary rail-way could be constructed a complete ellipsis, say of 2000 feet axis, and 1000 feet transverse diameter. If the steam wagon can be made to move satisfactorily, upon this ellipsis, of which I have no doubt, there need be no hesitation in adopting a final and specific arrangement of the whole plan. With a curvature of the above diameter, a serpentine road can be carried through the mountains without the expense of *numerous* stationary engines, which must be incurred by adopting the latest English engines (of Losh and Stephenson,) which can only run on a *straight* rail, or in a right line.

With the steam wagons, according to the English plan, as above noticed, it will be recollected, that when it is intended to alter the *course* of the rail-road, the wagon must halt upon a platform, which turns upon a pivot, so as to bring the front of the wagon in a line with the rails in advance.

Thus the rail-road must form a series of right lines and angles; and much time must be expended in making these stops, in turning, and getting in motion again. It will be also obvious, that this plan must multiply expense, by increasing the quantity of machinery, and the necessity of frequent repairs.

A due consideration of these facts, will shew the necessity of deciding in the first instance, what description of locomotive engine shall be used, *as this will entirely change the whole character of the system.*

The rail-road from Baltimore to the Ohio river, it is presumed, is to be double; or, in other words, one set of rails is to be appropriated to the transportation of heavy burthens to the west, which may, therefore, be called the west road, and another for the return eastward, of similar burthens to Baltimore, and may be called the east road.

Now, the elevation of the mountainous ridge between these two points, viz: Baltimore and the Ohio, is about 2700 feet above tide; but, as the rail-road may commence at its eastern end some considerable height above tide, we will suppose it 2600 feet, and the country descends from this ridge both ways to the above points, at which the contemplated rail-road begins and ends.

It has been assumed, that there will be three tons of produce coming eastward, to one of merchandize going westward. Taking these proportions as data, may we not inquire whether a *saving of time* in transportation, could not be effected, by locating and grading each pair of rails according to the directions of the transit, separately, and by different routes, so that variations in altitude, or elevation of the one pair, could cause no interference to the other pair of rails. This would allow the descending portions of each pair of rails to have a much greater inclination to the horizon than would be practicable, if both pair of rails were located upon one grading; for, in this case, they must necessarily be nearly upon a level with each other, at points taken at right angles to the direction of the road. If the features of the country do not forbid such a plan, it is clear, that an important saving in time may be effected. To illustrate which, let us attempt a comparison, by calculation, of the time necessary to make a trip from Baltimore to the Ohio river, and back again to Baltimore, by the two methods, viz:

1. First, let us suppose the two pair of rails located upon the same grading, and the two to be of the same height at all opposite, or corresponding points. Suppose the distance from Baltimore to the highest point of the road, to be 200 miles,

and the elevation 2600 feet, and suppose the distance from the said point to the Ohio river, to be 70 miles, and the descent 600 feet. Suppose the rails to be placed upon an exact level, except where it is necessary to have inclined planes and stationary engines; and suppose the inclined planes to rise one foot perpendicular for every 8 feet measured upon the inclined planes, and in order to abridge the calculations, without altering the result, let us suppose the whole elevation to be overcome by one inclined plane on each side the mountain; and suppose the stationary engines to be 30 horse power engines, and the locomotive engine a ten horse power, and to weigh six tons, with 18 wagons in train, these wagons to weigh, when empty, one ton each, let each of these be supposed to carry out westward, one ton of loading, and to bring back three tons each.

Then 6 + 36 = 42 tons × 2240 lbs. = 94080 lbs. ÷ 200 = 470.4 lbs. necessary to overcome the friction; and suppose the diameter of the wheels of the locomotive engine = 40 inches, and stroke of piston = 30 inches. Then the relative velocity of the train will be 125.66 inches, and that of the piston 60 inches, 125.66 : : 470.4 lbs. : 60 : : 985.17 lbs. pressure upon the piston, to give 470.4 lbs. at the circumference of the wheel.

A ten horse power = 320000 lbs. exerted through a space of one foot in one minute of time, 320000 ÷ 985.17 = 324.82 feet passed over by the piston per minute. Then 60 : 334.82 : : 125.66 : 680.28 feet per minute for the velocity of the train × 60 = 40816.88 feet per hour ÷ 5280 feet = 7.73 miles per

hour; 200 miles ÷ 7.73 = 25.87 hours to travel over 200 miles, going westward.

Upon the inclined plane it would be 94080 lbs. ÷ 8 = 11760 lbs. + 470.4 lbs. (the friction,) = 12230.4 lbs. thrown upon the stationary engine. A 30 horse engine = 960000 lbs. exerted through a space of one foot in one minute of time, 960000 ÷ 12230.4 = 78.49 feet per minute. This is the rate that a 30 horse engine will draw up the train.

Now, 2600 feet × 8 = 20800 feet for the length of the inclined plane, on the east side of the mountains, 20800 feet ÷ 78.49 feet per minute = 265 minutes ÷ 60 = 4.42 hours in ascending this inclined plane.

It would probably not be prudent to lower the train down the inclined plane, by means of a wheel and brake, at a greater velocity than 60 feet per minute. 600 × 8 = 4800 feet for the length of the inclined plane, on the west side of the mountains, 4800 feet (descending) ÷ 60 feet per minute = 80 minutes ÷ 60 = 1.33 hours in descending the western inclined plane.

70 miles ÷ 7.73 miles per hour = 9.05 hours consumed in running over the 70 miles (level) to the Ohio river.

25.87 + 4.42 + 1.33 + 9.05 = 40.67 hours in going from Baltimore to the Ohio.

In returning from the Ohio river, we have 18 × 4 = 72 + 6 = 78 tons × 2240 = 174720 lbs. ÷ 200 = 873.6 lbs. necessary to overcome the friction. Now, the result will be the same if we seek for the velocity directly from this force without regarding the velocity of the piston; thus, 320000 lbs. ÷ 873.6 lbs. = 366.3 feet per minute × 60 = 21978 ÷ 5280 feet = 4.16 miles per hour. 70 miles ÷ 4.16 miles per hour = 16.82 hours in running over 70 miles, with the 78 tons.

Upon the ascending inclined plane, it will be 174720 ÷ 8 = 21840 lbs. + 873.6 (for friction,) = 22713.6 lbs. thrown upon the stationary engine.

A 30 horse power = 960000 lbs. exerted through a space of one foot in one minute of time ÷ 22713.6 lbs. = 42.26 feet per minute.

4800 feet of ascending inclined plane $\div$ 42.26 $=$ 113 minutes $\div$ 60 $=$ 1.88 hours in ascending to the summit of the mountain.

The descending inclined plane eastward $=$ 20800 feet $\div$ 60 feet per minute $=$ 346.66 minutes $\div$ 60 $=$ 5.77 hours in descending the inclined plane on the east side of the mountain.

And 200 miles $\div$ 4.16 miles per hour $=$ 48.07 hours in returning the 200 miles to Baltimore.

$16.82 + 1.88 + 5.77 + 48.07 = 72.54$ hours in returning from the Ohio river to Baltimore, $+$ 40.67 hours in going out $=$ 113.21 hours in going and returning, on these suppositions.

2. Let now the two roads be supposed located upon separate routes, with the descending portions of each road to have a gradual descent.

In this method, the ascending portions are supposed precisely similar to those in the first method, and the time of ascending will be the same, we have, therefore, only to calculate the time employed in this last method in running from the top of the mountain to the Ohio, upon the west road, and from the top of the mountain to Baltimore upon the east road.

First, then, of the time employed in running from the top of the mountain to the Ohio river; here we have 70 miles $\times$ 5280 $=$ 369600 feet $\div$ 600 (the descent,) $=$ 616 feet. That is a descent of 1 foot in 616 feet. Then 94080 lbs. (the weight in going out,) $\div$ 616 feet $=$ 152.72 lbs. exerted in the direction of the rails.

The friction $=$ 470.4 lbs. $-$ 152.72 lbs. $=$ 317.68 lbs.; this is the force necessary to propel the train on this part of the road. 320000 lbs. $\div$ 317.68 lbs. $=$ 1007.3 feet per minute $\times$ 60 $=$ 60438 feet per hour, $\div$ 5280 $=$ 11.44 miles per hour; 70 miles $\div$ 11.44 $=$ 6.12 hours in running the 70 miles to the Ohio river.

From the top of the mountain to Baltimore, 200 miles × 5288 = 1056000 feet ÷ 2600 (the descent,) = 406.15 feet. That is a descent of 1 foot in 406.15 feet. 174720 lbs. (the weight in returning,) ÷ 406.15 feet = 430.18 lbs. exerted in the direction of the rails. 873.6 lbs. (the friction,) — 430.18 lbs. = 443.42 lbs. necessary to propel the train on this part of the road.

320000 lbs. ÷ 443.42 lbs. = 721.66 feet per minute, × 60 = 43299.6 feet per hour, ÷ 5280 feet = 8.2 miles per hour.

200 miles ÷ 8.2 miles per hour = 24.39 hours in returning from the mountains to Baltimore.

SUMMARY.

1st method—Going.

	hours.
Time in going 200 miles, (level,)	25.87
Do. in ascending the eastern inclined plane, . .	4.42
Do. in descending the western inclined plane, .	1.33
Do. in running 70 miles, (level,)	9.05
Total time in going, ...	40.67

1st method—Returning.

	hours.
Time in running over 70 miles, (level,) . . .	16.82
Do. in ascending the western inclined plane, .	1.88
Do. in descending the eastern inclined plane, . .	5.77
Do. in running over 200 miles, (level,) . .	48.07
Total time in returning, ...	72.54
First trip, ...	113.21

2d method—Going.

	hours.
Time in going 200 miles, (level,)	25.87
Do. in ascending the eastern inclined plane, . .	4.42
Do. in running over the gradual slope of 70 miles,	6.12
Total time in going, ...	36.41

2d method—Returning.

	hours
Time in running over 70 miles, (level,)	16.82
Do. in ascending western inclined plane, . .	1.88
Do. in running over the gradual slope of 200 miles,	24.39
Total time in returning, ...	43.09
Second trip, ...	79.50
First trip, ...	113.21
Second trip, ...	79.50
Time saved, ...	33.71

To those unacquainted with these subjects, it may be necessary to state, that the above calculations are only intended to establish a principle. That in those parts of the route where the country is most level, the two pair of rails could be located upon the same grading; and where the ascents and descents were the greatest, the two pair of rails could be located upon different routes, that is, upon different gradings.

And it may be well to state, further, that the estimate of time in the above calculations, is not intended to be taken as positive, but only comparative, in which sense, such calculations are to be depended upon. The positive time in making a trip, will, no doubt, be greater than what is given above; for it will, perhaps, not be practicable to keep every part of the road in such complete repair, that the friction will be no more than the

two hundreth part of the weight of the train. And again, in the above assumptions, but one ascent, and one descent, is supposed upon each pair of rails; whereas, the probability is, that the road will ascend and descend, and again ascend and descend a number of times. This will, of course, very much increase the aggregate length of the inclined planes, and this, of necessity, will increase the time of passing through.

It has been stated by Gray, and quoted by Strickland, that a locomotive engine will work goods over an elevation of $27\frac{1}{2}$ feet to the mile; they have taken care, however, not to tell us what weight of goods could be thus "worked over," and omitted to make any calculations, (which, as engineers, they should have done,) to ascertain the quantity which could be taken over this elevation, at a given velocity, with a given power, or with what velocity a given weight could be conveyed. Now, we will undertake to say, that this ascent is by far too much, unless the wagons are to go up it entirely empty; but as it is best to make no assertion without giving the necessary proof, whenever it can be done, we will now proceed to show, by calculation, that this elevation is too great. Let us first suppose a given weight, and calculate the velocity, and afterwards assume a given velocity, and calculate the weight

which our given power would convey up the ascent of $27\frac{1}{2}$ feet per mile. First, then, suppose a ten horse power, and 78 tons; $78 \times 2240 = 174720$ lbs $\div 200 = 873.6$ lbs. for friction, and 5280 feet : 27.5 feet : : 174720 lbs. : 910 lbs. $+ 873.6 =$ 1783.6 lbs. to be overcome by the locomotive engine. A ten horse engine $= 320000$ lbs. exerted through a space of one foot in one minute of time, $320000 \div 1783.6 = 179.4$ feet per minute $\times 60$ $= 10764$ feet $\div 5280$ feet $= 2.03$ miles per hour; this is too slow for the purposes of trade on this rail-road, and besides, it would require too great a pressure of steam, more than the boiler of a locomotive engine could safely bear, for these boilers are, of necessity, large in diameter, say four feet, to give room for the furnace inside of the boiler.

Suppose now a speed of five miles per hour, and let it be required to find what weight a ten horse locomotive engine can convey at this speed. $5280 \times 5 = 26400$ feet $\div 60 = 440$ feet per minute; $5280 \div 27.5 = 192$, that is an ascent of 1 foot in 192 feet. Let x represent the unknown weight, then $\frac{x}{192} =$ the tendency of the weight down the plane by the action of gravity, and $\frac{x}{200}$ $=$ friction, consequently, $\frac{x}{192} + \frac{x}{200} = \frac{320000}{440}$ this equation ordered gives $x = 71242$ lbs. $= 31$ tons,

1802 lbs.; but the locomotive engine itself weighs six tons, and each of the 18 wagons weighs 1 = 24 tons, so that 31 — 24 = 7 tons, 1802 lbs. which is all the engine can take up at this speed.

In the construction of public works of great magnitude, it is all important to take into consideration every item of expenditure, and examine well into the quality, quantity, and price of the various materials to be procured for the contemplated object, keeping in view, at the same time, the durability of the same. By attending well to these particulars, and not suffering ourselves to be governed too rigidly by works of a similar character, the facilities for procuring the materials of which, may have been quite different from the case in hand, we often are enabled to construct works cheaper and better than those of other districts or countries. For example, in the greater part of England, stone of sufficient hardness for the construction of public works, is not to be had, and perhaps, owing to this circumstance alone, all her rail-ways which I have seen, or heard of, except those at the London dock, are propped up upon blocks, either of stone or of wood, such as the knees and other parts of old ships, &c.; these being placed at the distance of about 3 to $3\frac{1}{2}$ feet, serve to support a rail either of cast or malleable iron. Now, this fact should not, by any means, lead us to suppose that this is the best of all pos-

sible methods to construct a rail-road in any part of the world, and under every possible circumstance; for, if hard building stone, of as good quality as is known to abound in all the country between this and the Ohio river, could be had in England, we might infer, that a different method of construction had been there adopted. The object aimed at, is to have a smooth rail of iron, (of which metal, on account of the price, we are to be as sparing as possible, keeping the goodness of the works in view,) of the proper width upon the face of it, say $1\frac{1}{2}$ to $1\frac{3}{4}$ inches, and this rail firmly fastened to its substratum, and supported in such a way as to be able to bear a great weight at all its points, and all the materials to be of an imperishable nature.

If an engineer, who had never heard of supporting rails at points remote from each other, were directed to construct a road, which should have the above properties, and an inexhaustible quantity of good stone presented itself in the vicinity, would he entertain the plan of making the iron rails of sufficient strength to admit of being propped up only at points three or four feet asunder? Would he not, most probably, first think of supporting his rails by the stone at all points? This is a method I proposed some years ago, some time before the Quincy rail-road was commenced.

It was published in the Baltimore American. It has been, however, modified and improved. The most improved plan which has come to my knowledge, appears to be this; after the road has been graded, two trenches (one for each rail,) are dug, of sufficient depth to be below the action of the frost, and about eighteen inches wide; these ditches are filled to near the top with stone, broken as small, or rather smaller than for McAdam's road, and these being well pounded in with heavy rammers to a suitable height, the trenches are ready to receive the blocks of granite, or other hard stone. These being riven into blocks of about 14 to 15 inches wide, and 12 or 14 in thickness, and in length, as long as may be, the ends are dressed off with a coarse groove horizontally across one end, about the middle of the depth, and a tongue upon the other end, of exactly the corresponding reverse form. The bottoms and sides of these blocks it is not necessary to dress; the tops are partially dressed. They are now laid down in the trenches, and firmly bedded on the broken stone, the horizontal tenon or tongue of the one fitting into the corresponding groove of its fellow. The tops are next dressed accurately to a straight edge, for a space, something wider than the bar of iron which is to form the rails; from each side of this space, the stone is dressed

off a little sloping each way, so that gravel, dust, ice, &c. will not so readily lodge thereon. The bars of *wrought* iron, 1 by $1\frac{1}{2}$ or $1\frac{3}{4}$ in., which are to form the rails, are left their full length as they came from the rolling mill; one end is made forked, or in form of the letter V, the other end is sharpened so as to be an exact counterpart; holes are drilled through these bars 3-8 of an inch in diameter, and countersunk; the bars are now ready for laying down upon the stone; one rail is laid down and kept in advance of the other, and as the other is laid down, it is kept accurately at the proper distance from the first by an iron or steel gauge, notched, to receive the rails, and carried along as the work advances, keeping it at right angles to the rails.

The rails are fastened to the stones by iron pins driven in, in a manner called fox-wedging. The stones being first drilled, by drilling through the holes in the rail, and all of them drilled accurately to the same depth by means of a gauge; the pins being made all accurately of the same length, to correspond, with small heads, to fit into the countersink. The lower ends of all the pins are slit, and a wedge partly driven into this slit previously to introducing it into the hole. This forms what is technically called fox-wedging. The pins are now driven home, and the road being

carried through in this way, it is finished and ready for the reception of the carriages. This mode of fox-wedging will make it difficult to purloin the iron bars.

Query.—What inclination must the road have, supposing the two pair of rails to be laid upon the same grading, and consequently having the same inclination, and in the same direction, to cause the trains to move with equal velocities in both directions; supposing an equal power exerted by the engines, while running in both directions, and taking the weight of goods conveyed towards Baltimore as being three times as much as is conveyed to the Ohio?

Answer.—Let us take 6 tons for the weight of the locomotive engine; and 18 wagons, each weighing when empty, 1 ton; and let each of these be supposed to carry westward 1 ton, and bring back 3 tons each:

Then $18 \times 2 = 36 + 6 = 42$ tons $\times 2240 = 94080$ lbs. $\div 200 = 470.4$ lbs. for the friction while going westward, and $18 \times 4 = 72 + 6 = 78$ tons $\times 2240 = 174720 \div 200 = 873.6$ lbs. for the friction while coming eastward. Let x = an unknown length of the rails, the descent corresponding to which shall exactly = 1 foot.

$$\text{Then } 873.6 - \frac{174720}{x} = 470.4 + \frac{94080}{x} = 403.2 = \frac{268800}{x} =$$

$$268800 \div 403.2 = x = 666.6666 \text{ feet.}$$

$$666.6666 : 1 :: 5280 : 7.92 \text{ feet.}$$

That is, the required descent of the road towards Baltimore is 7.92 feet per mile.

But it is the opinion of many, well qualified to judge in this particular, that there will be 4 times the weight brought eastward, to what will go westward. If this be taken as the true data, and allowing 24 tons for the weight of the steam and other wagons, and 14 tons of merchandize westward, and 56 tons of produce brought eastward.

Here $24 + 56 = 80$ tons $\times 2240 = 179200$ lbs. $\div 200 = 896$ lbs. for the friction, while coming eastward; and $24 + 14 = 38$ tons $\times 2240 = 85120 \div 200 = 425.6$ lbs. for the friction, while going westward,

$$\text{Then } 896 - \frac{179200}{x} = 425.6 + \frac{85120}{x}$$

This equation being ordered, gives us $x = 561.9$ feet.

$561.9 : 1 :: 5280 : 9.39$ feet.

That is, a descent of 9.39 ft. per mile towards Baltimore, will give the train an equal velocity, going and coming, with an equal power in each direction, and four times the loading while coming eastward, to what is conveyed westward.

A more particular description of a Locomotive Engine to run upon a Serpentine road.

The force of the steam in this steam wagon, is applied to all the wheels which support the weight of the engine, and the re-action of this force, is sustained wholly by the friction, between the wheels and the rails, caused by the weight of the engine and wagon, thereby avoiding the necessity of a rack-way, which is objectionable on account of the increased expense, the increase of friction caused by it, and the liability of the cast iron rack-way to break, and be out of order. At first view this steam wagon would appear but little different from the steam wagon proposed by Losh and Stephenson, in England; but their wagon will not run upon a serpentine road.

To adapt the steam wagon, which runs or proceeds by the mere contact of the wheels with the rails, and, therefore, not requiring a rack-way, or any other similar contrivance, to run upon a serpentine road, is what I claim as my invention, and which I describe as follows:

In this steam wagon, there are four revolving axle-trees or shafts, and but four wheels, (except the guide wheels to be described hereafter,) one wheel being made fast to one end of each shaft.

The face of these wheels have a groove in them, adapted to the rails of the road. Each of the shafts is bent, so as to form a crank, which is effected by bending the shaft at right angles to its length, in which direction it extends a distance equal to half the intended stroke of the piston;—it is then bent again, forming another right angle, and extends parallel to the general length, a distance sufficient to form the wrist, and then returns again into the line of the general length.

These cranks are near to the wheels; leaving, however, a sufficient space between them and the wheels, for a neck, upon which neck, and another, at the end of the shaft most remote from the wheel, the shaft revolves. Two of these shafts are mounted in a frame, one of them a few inches in advance of the other, with the wheels on each side of the frame, and the inner end of each shaft extends no further than the crank upon the other shaft. This forms the forepart of the wagon. Another similar frame, pair of wheels, and shafts, forms the hinder part of the wagon. These two frames may be connected together in the usual manner of the common wagon, by a bolt in a line, and equidistant between the two foremost wheels, and free to turn upon said bolt, or they may be connected together at a point equidistant from all the wheels, by a bolt or any other

method, forming a hinge, so as to allow the foremost pair of shafts, to alter their position of parallelism, to the other pair of shafts, so far as the curvature of the road may require. The object of connecting the two frames together, at a point equidistant from all the wheels, is to cause the hinder wheels to follow more accurately the curve lines described by the foremost wheels.

Upon these two frames thus connected, the boiler is mounted. There is a steam cylinder and piston, and valves complete, attached to each of the cranks, entirely separate and distinct from each other. The aggregate sum of the numbers of cubic inches, which these four cylinders would hold, is equal to that of the two, when two cylinders are used, or of the one when one is used; in other words, the power is divided into four equal parts, each part being exerted upon its respective wheel.

From the boiler to each of these cylinders, tubes extend, for the free admission of the steam from the boiler to the cylinders, upon the pistons of which it acts in the usual way of pressure engines. It should be remarked, that as there is a change of relative position in the two frames, with respect to each other, there will also be a change of relative position between the forward frame and the boiler. This will necessarily require steam tight

joints in the tubes which convey the steam from the boiler to the cylinders belonging to the forward frame, and those joints must allow of the requisite motion.

The object of having a separate cylinder to each shaft, and a separate shaft to each wheel, independent of each other, is that the wheels which describe the greater curve, while turning upon a serpentine road, may revolve more rapidly than the others, and still continue to be urged by the steam with as much force as before.

In order to keep the wheels of the steam wagon accurately upon the rails of the road, another frame, in advance of the steam wagon, is connected with the foremost frame belonging to the same, by hinges, which admit the frame to rise up or fall down; but admit not of a lateral motion: that is, it cannot be turned aside, without carrying the foremost frame of the steam wagon along with it. Under the forepart of this frame are four wheels, two for each rail of the road. These wheels stand in an oblique direction, with respect to a vertical line, forming about thirty degrees with the vertical line, and each pair forming an angle of about sixty degrees with each other. Each pair leans off from each other at the top, with the lower part of each converging towards each other, and resting upon the rail of the road, and being groov-

ed upon their faces so as to fit the rail while standing in this oblique position. They are all mounted in the same frame, and are free to revolve, each upon its own axis, independently of the others.

These wheels may be called the guide wheels, which sufficiently describes their use. The place of these four wheels might be occupied by two, in a vertical position, one for each rail, with grooves to fit the rails; but the lateral force necessary to turn the foremost frame of the steam wagon, might, by pressing the flange of the guide wheel hard against the side of the rail, cause serious friction, and might even cause the flange of the wheel to run over the rail; all of which will be obviated by using the four oblique wheels. The above wagon would admit of a boiler large enough for a ten horse power.

Another modification is to have but two wheels, to which the steam is applied, with each a separate shaft and cylinder, similar to one of the pairs of steam wheels described above, and the guide frame and guide wheels, similar to those already described, except that in this case, the two frames are firmly fastened together, forming, as it were, but one frame. The boiler in this plan is to be sustained partly by the guide wheels, but mostly by the two steam wheels; that is, the greater part of the weight is supported by the steam wheels.

This last modification has the recommendation of simplicity, and on this ground I am induced to recommend it as the better plan of the two. It would probably not be prudent in this modification, to use a boiler of more than five or six horse power, for fear of concentrating too great a pressure upon one point of the rail-road. It is hardly necessary to state, that the weight of the train in this case would be less, being proportional to the power.

With a view of removing any sand, gravel, ice, snow, or other matter, from off the rails, I propose to use scrapers to go before the wheels, to scrape and clean the rails.

NEW STEAM ENGINE.

The author, having recently received the patent in Europe, is now enabled to lay before the reader an extract from the specification of the improvement of the Steam Engine alluded to in the preface.

SPECIFICATION

Of new and economical methods of using heated air, gases, elastic fluids, and products of combustion, which are available to the increase of steam power.

These consist in employing or using, in whole or in part, the air which is *heated* while passing through the fire of the furnace attached to the steam engine, together with the heated gases, elastic fluids, or products, set at liberty, or given out by the burning fuel in the same. By means of sundry appliances and machinery, which are added or affixed to the steam engine, to *force* or *throw into* the boiler, either below or above the surface of the water in the same, the aforesaid heated elastic fluids, or products of combustion, thereby causing them to mix or unite with the steam. Thus availing myself of the caloric and agents, which are ordinarily suffered to escape through the flue or chimney into the atmosphere, and are lost. This may be put into practice by an indefinite variety of methods.

One method is, to place a pneumatic forcing pump, which we will call the *gas-pump*, on the top of the boiler of the steam engine; a pipe, or tube, extends up from the furnace below, through the water and steam in the boiler, and enters the bottom of the gas-pump chamber, where there is a valve opening *upwards*. By the side of this valve there is another valve opening *downwards*, into the cavity of the boiler. The piston of the gas-pump is driven by the engine. From the upper part of the boiler, commonly called the steam chamber, a pipe extends to the steam, or working cylinder of the engine, which cylinder is of a construction no way different from that of the steam engine in common use.

Operation.—As the piston of the gas-pump rises, the valve which opens upwards will be forced open by the laws of atmospheric pressure, causing the heated elastic fluids and products of combustion to follow the piston. The other valve being kept closed by the pressure of the steam in the boiler, the heated air, gases, and other heated products of combustion, rise from the burning fuel in the furnace, and passing up through the pipe and the valve, fill the chamber of the gas-pump; the cubic contents of which may be to those of the steam, or working cylinder, as 169 to 256, or thereabout. On the descent of the piston, the inlet valve closes.

and as soon as the descent of the piston, by compressing the heated air, gases, and other heated products of combustion contained in it, causes their elastic force to become greater than the elastic force of the steam in the boiler; the valve in the boiler opens, and the contents of the gas-pump are driven into the boiler, at a temperature nearly equal to what it was in the furnace, where coming into actual contact, and mixing with the steam, they give out a portion of their caloric to the steam, and the temperature of the mixture will be higher than was that of the steam before the injection of said gases. The increased temperature will cause a corresponding increase of the elastic force; the mixture of steam and other heated elastic fluids thus formed, passes on to the working cylinder of the engine, where, after acting by their pressure upon the piston of that cylinder, they are either suffered to escape into the atmosphere, or they are conveyed to a condenser, where the steam and aqueous parts of the mixture are condensed, in the same manner as steam in condensing engines. The water thus formed, the injected water, with the air, gases, &c. are pumped out together. The above arrangements of parts has been specified on account of the ease with which it may be understood.

Another modification, is to immerse the gas-pump in the boiler with its upper flange upon the top of the boiler. A tube, open at both ends, extends from near the upper part of the steam chamber, internally down along the side of the gas-pump, and enters the bottom of the same. By this arrangement, as the piston of the gas-pump rises, the chamber below the piston will be filled with steam, and as no valves are placed in this tube on the ascent of the piston, this steam will be returned into the steam chamber; the use of this is to keep the packing of the gas-pump continually damp, so as to prevent its being burned. The inlet and outlet valves are placed upon the top of the pump, the piston rod working through a stuffing box, a tube extends from the furnace to the inlet valve, and another tube extends from the outlet valve to the steam chamber. The gas-pump may be also placed externally on the end or side of the boiler, and be a double acting pump, with a pair of valves, as before described, at each end thereof. In this plan, an elastic metallic piston may be adopted; one method of making which, is to substitute for the packing of hemp, a packing, or gasket of card-wire, which is applied in the same manner as the packing of hemp.

In the above methods, if it be intended to take into the gas-pump a larger part, or the whole of the heated elastic fluids and products of combustion, a damper, or valve, may be placed in the flue or chimney above the tube leading to the gas-pump, which damper, after the engine is in operation, may be totally, or partially closed. If it be entirely closed, the draught and the consumption of the fuel in the furnace will be in proportion to the capacity of the gas-pump, and the number of strokes made by its piston in a given time.

THE END.